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## APPLICATIONS OF POSITIVE RAYS.

*Rays of Positive Electricity and their Application to Chemical Analysis.* By Sir J. J. Thomson, O.M., F.R.S. Pp. vii + 132 + 5 plates. (Longmans Green and Co., 1913.) Price 5*s.* net.

ALL physicists and chemists will welcome this account by the author of his wonderful series of researches, begun seven years ago, on positive rays. This name, "positive rays," is preferable to "canal-rays," originally applied to the stream of positively-charged particles which passes through a hole in a flat cathode; and the author's choice of the word "particle" to denote an atom carrying a positive charge, and the word "corpuscle" for what is generally now termed an electron, will not be challenged.

After a description of Goldstein's experiments, an account is given of Wien's discovery that these rays are deflectable by powerful magnetic fields. The theory of the deflection is shortly and clearly stated; and also the theory of the electrostatic deflection of a particle. Then follows an account of the author's first experiments, made in 1906, for which he devised an apparatus allowing of the simultaneous application to a bundle of positive particles both an electrostatic and a magnetic force. The arrangement is so devised as to apply these forces at right-angles to each other; and the result, as Sir Joseph Thomson has described in numerous papers and lectures, is to convert the luminous point (if a Willemite screen be used) into a parabola. The position of the parabola on the screen is conditioned by the intensity of the forces applied; but if these be kept uniform, it depends, *inter alia,* on the masses of the particles. Now the mass is simply related to the atomic or molecular weight, and hence the nature of the particles can be identified.

It is found, however, that the same mass may hold one or more charges; hence in deducing the atomic weights, this has to be borne in mind.

Descriptions are given, with figures, of the instruments employed; but from a practical point of view the figures might have been improved. In Fig. 6, for example, connections for maintaining an electrostatic field are not shown, and neither in that figure nor in Fig. 13 is any arrangement shown for introducing gas. Indeed, one wonders, in reading this book, what gases were present to cause the kathode rays to pass, for they cease in a high vacuum. Sir Joseph Thomson points out the necessity for removing air very thoroughly with a pump before applying absorption with cooled charcoal; are the residual gases traces of neon and helium? or are they minute traces of oxygen and nitrogen, corresponding to the vapour-pressures of the gases condensed on the charcoal? or do the conducting gases come off the electrodes, or off the walls of the tube? It would have been useful if information on this point had been given. In this connection, on p. 25, we are told that the gas to be used is kept in *A*, Fig. 13; but there is no means of introducing a gas into *A*; the gas is said to be stored over a column of mercury; how then is mercury vapour excluded? The same want of precision applies to the description of the photographs. It is exceedingly difficult, if not impossible, to follow on the plates the peculiarities described in the text; for example, Fig. 28 is described on pp. 48 and 49. Eight parabolas are mentioned in the text, but only five appear in the photograph. Possibly the negatives may show more than the prints; but if so, it should have been stated, and a diagrammatic reproduction of the photographs should have been given. In this connection, too, it may be mentioned that there is a considerable number of misprints; the well-known "effect" is due to Doppler, not Döppler; and commas are frequently substituted for semi-colons.

The ingenuity with which various effects are analysed and alternative hypotheses tested is extraordinary; Sir Joseph Thomson possesses scientific imagination in the highest degree, combined with the power of mathematical presentation and wonderful experimental skill. Take the following passage:—

> "We can form an estimate of the magnitude of the attraction between a neutral atom and a corpuscle. From the measurement of the plates we find that there are negatively electrified atoms of hydrogen with a velocity as large as $2 \times 10^8$ cm./sec. This means that a neutral atom of hydrogen is able to capture a corpuscle even though it is moving past it with this velocity. This capture, however, would not take place unless the work required to remove a corpuscle from the surface of a neutral atom of hydrogen were greater than the kinetic energy of a corpuscle moving with the velocity of $2 \times 10^8$ cm./sec. This kinetic energy is equivalent to the fall of the atomic charge through 11 volts; hence we see that it must require an ionising potential of more than 11 volts to liberate the corpuscle from a negatively electrified atom of hydrogen. The same considerations show that to liberate the corpuscle from a negatively electrified atom of carbon would require at least 0·9 volt, while for oxygen the corresponding ratio would be 0·7 volt. It must be remembered that these are merely inferior limits; the actual values may be much larger."

It is interesting to note that evidence has been obtained of the transitory existence of such groupings as $CH_3$, $CH_2$, and CH, as well as of

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groupings of two and of three carbon atoms; the last are produced only when the vapours of complex carbon compounds are induced to form "positive rays."

The question of multiple charges carried by an atom is discussed at considerable length; it would appear that a mercury atom may carry as many as 8 charges; an atom of krypton, 4 or 5; one of argon, 3; one of neon, 2; of nitrogen and of oxygen, 2; and of helium, also 2; no hydrogen atom with more than one charge has been observed. The larger the number of charges carried, the fainter the line. But the intensity of the parabolic line, whether seen on a Willemite screen or photographed, is by no means proportional to the amount of element producing it. The hydrogen parabola, for instance, is always much more intense than would be accounted for by the relative amount of hydrogen present. To prove this, a most ingenious device was adopted; a parabolic slit in the screen was interposed between the source of the rays and a metallic box, connected with an electrometer; by altering the intensity of the magnetic field, the parabolas were made to fall on the slit, and the rays passed through into the box, and registered their intensity on the electrometer. In this way the relative quantity of the gaseous elements present was estimated with fair accuracy.

Proof was also obtained that helium is a monatomic gas, while oxygen and hydrogen are diatomic; for in the discharge-tube, besides detachment of a corpuscle from a molecule, the splitting up of a molecule into its constituent atoms takes place.

Chapters follow on retrograde and on anode rays; and Stark's interesting observations on the Doppler effect are described and amplified; also a short account of the spectra produced by bombardment with positive rays.

Next follows a chapter on the use of positive rays for chemical analysis; the preface states that "one of the main reasons for writing this book was the hope that it might induce others, and especially chemists, to try this method of analysis." I fear that it will not have this result. It is a pity that Sir Joseph Thomson in this chapter had not given a more detailed account of his methods, with more elaborate diagrams of the apparatus. Even to one skilled in work of this nature, what appear no doubt commonplaces to him require elucidation. For example, how many amperes are necessary to incite his magnets? What is the size of the magnets? What electric field is required? What voltage must be applied to the plates giving an electrostatic field? One would require to visit the Cavendish laboratory, or to trouble its director with correspondence before one could set up an apparatus in working order.

A discussion then follows of Mr. Aston's interesting investigation of neon, with the object of ascertaining whether neon, which has the atomic weight 20·2, contains a gas of atomic weight 22; the existence of the latter is indicated by positive rays in neon. To my mind it is scarcely credible that a mixture of gases, separable by diffusion, as Mr. Aston finds, cannot be separated by distillation and yet neither Mr. Watson, who determined the atomic weight of neon, nor Mr. Aston, who repeated Mr. Watson's experiments, have been able to effect any separation by fractionation. Further work, however, will no doubt settle the question. The existence of "$X_3$" is next treated of; and the reasons for believing it to be a hydrogen "ozone" appear to be cogent.

Finally, Sir Joseph Thomson deals with the continuous production of helium when certain substances are bombarded with kathode rays. Again, he does not inform us what gas was present. He is rightly very cautious in drawing any definite conclusions from his experiments; but at present his bias is in favour of the possibility of disintegration; that the matter bombarded disintegrates into helium, and some other "elementary" form of matter. He says:—"The view that helium can be got from other chemical elements raises questions of such a fundamental character that few will be prepared to accept it until every other explanation has been found to be untenable." The production of helium from radium, from niton, from thorium, and from actinium is now accepted as an undoubted fact; questions of "a fundamental character" have been raised and answered; and it appears to me to need a very small stretch of imagination to suppose that while some "elements" spontaneously undergo exothermic changes with evolution of helium, others require external sources of energy before disruption takes place.

W. R.

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## *GEOLOGY AND MINERALOGY.*

(1) *The Earth: Its Genesis and Evolution considered in the Light of the most recent Scientific Research.* By A. T. Swaine. Pp. xix + 277 + xi plates. (London: C. Griffin and Co., Ltd., 1913.) Price 7*s.* 6*d.* net.

(2) *Grundzüge der geologischen Formations- und Gebirgskunde.* By Prof. A. Tornquist. Pp. iv + 296. (Berlin: Gebrüder Borntraeger, 1913.) Price 6.80 marks.

(3) *Determinative Mineralogy.* With Tables for the Determination of Minerals by means of their Chemical and Physical Characters. By Prof.

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